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Chimney Ventilation System in Minster School, Southwell

-A successful strategy or a redundant building element

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Abstract:

The Minster school is a Church of England school in Southwell town of Nottinghamshire which won many awards for outstanding contribution in design and environmental solutions in 2009. It uses passive strategies, dominant being, the judicious use of natural ventilation to achieve comfortable internal environment, hence the interest in the project. Each classroom has distinctly designed external window with top and bottom opening, controlled manually and by Building management system respectively. Each class has single sided ventilation and a chimney for stack ventilation. The post occupancy survey and site observations highlighted issue of downdraught from chimneys, hence discomfort. Through onsite data records and computer simulations in two classrooms, Class-A (South East) and B (North-West), it was found that the chimneys terminated in the direction of wind and the dampers were malfunctioning, which forced a downdraught effect in winters when the internal temperature is more than external. By providing BMS controlled chimney vents, it was found that comfortable hours can be increased from 5.62% to 13.73% and 5.27% to 11.58% in Class-A and B, respectively. Moreover in summers, in medium wind velocities the chimneys were found to be ineffective for stack ventilation and by removing them the comfortable hours can be much increased. Overall the paper summarises the findings of the study conducted on the chimney ventilation design, its shortfalls and opportunities for substantial improvements.

Keywords: Classrooms, Natural ventilation, Environmental performance, Thermal comfort.

1. INTRODUCTION

To raise the quality of education in England, the government has set up rather challenging targets to achieve. In 2004, a capital investment, 'Building Schools for Future' (BSF), was prefaced to renew or rebuilt every secondary school in UK to a sustainable school by 2020. In addition to this, government aims to substantially reduce carbon emissions by 2016 and thereafter have every school building as zero carbon. These attempts are to transform the way we learn and explicitly link the quality of education with school design. These programmes imposed huge responsibilities on architects to design school buildings environmentally as well as socially sustainable, hence influencing student's behaviour in a positive direction and improving their performance.

In UK, BRE (Building Research Establishment) has established a set of environmental standards and assessment rules for non-domestic buildings. BREEAM (Building Research Establishment Environmental Assessment method) assesses a building in nine sections, i.e. Management, health and wellbeing, energy, transport, water, materials, waste, land use and Ecology and pollution. Each section is scored and the final rating is based on the weighted scores which signify sustainability.

The Minster school was completed in 2007 under BSF programme and won RIBA (Royal Institute of British Architects) East midlands and Sorell award in 2009 for high architectural standards and contribution to the local environment. The school design has been assessed to have a 'very good' BREEAM rating. The design engages passive strategies for comfort like daylighting and an explicitly designed ventilation system in classrooms.

2. THE MINSTER SCHOOL

The Minster school is a Church of England secondary school in Southwell district of Nottinghamshire and is closely linked to Southwell Minster church. The challenge for

architects Penoyre and Prasad was to recreate the relation between 900 years old school and community; and to design a building coherent to its surroundings as the site is located between a small Georgian town, Southwell and countryside (Figure.1). The design of the school aims to create a rich architectural experience, minimise energy consumption, be flexible for future expansions and conceive a link between school and the community.



Being the Church of England school, the building was supposed to orient in the direction of the naïve of Southwell minster church i.e. East-West, but to avoid lower solar angle and glare, the architects followed an intermediary axis, hence oriented North-West and South-East. The school functions are divided two main wings each addressing different space use. The

Western strip contains impressively equipped communal facilities like assembly hall, recital room, theatre, common rooms, and café and at the south tip of this wing is the sports hall and gym which are accessible to the local public, out of school hours also (Figure.2). The eastern side of the school has three classroom wings which projects into the landscape forming courtyards between each other. Connecting functions in east and west is the central spine of the school or the 'heart space'. This double height 8M wide space, proportioned to the width of Southwell Minster, is used partly for circulation and partly as gathering space for variety of activities. The drama studio, assembly halls can be flexibly combined together by moveable walls to accommodate large gatherings. Demountable partitions and walls non-load bearing between the classrooms have been provided for long term adaptability and future expansions.

2.2 Sustainability

The Heartspace is brightly lit by a series of roof-lights which contributes in naturally lighting the rooms lined along it, like library, staffroom, assembly hall etc., through the clerestory windows. Material with high thermal capacity has been used in interiors for night time ventilation in order to moderate the temperature variation during

the day time. The classrooms have specifically designed windows with top and bottom operable panels (Figure.3.) to have one-sided ventilation. The top pane is controlled by BMS which opens when the temperature and CO2 quantity exceeds above the benchmark levels in

13: MFL/Social studies
14: Design and technology
Figure 2 Ground Floor Plan
Source: Penoyre and Prasad LLP



Figure 3 Section through Classroom wing showing Ventilation strategies. Source: Author

Figure.1. The Minster School. Source: Penoyre and Prasad LLP.





the classrooms. Each classroom is further ventilated through chimneys that vent to the roof. The chimneys stack ventilates the classrooms without any cross transfer of noise between them which would have happened had they been cross ventilated.

3. COMFORT ANALYSIS

3.1. Observations and Data Monitoring

A study trip of the school was done to understand its design and environmental performance. The intention was to focus research around user's feedback and selfobservations. A post occupancy evaluation through BUS methodology (Adrian Leaman and Bordass, 2001) was carried out. 200 survey forms were given to the members of the staff to record their feedback about their experience in the building out of which 50 were received back and data was contemplated. Most of them were satisfied and appreciated the design and the luminous environment of the school (Figure.4), but, expressed discomfort in summers due to overheating. Although the building is mechanically heated still they were neutral about thermal comfort in winters rather than comfortable. A common comment from a Figure 4 Post Occupancy Survey. Source: Yanti Chen number of users was that sometimes the



(Ph.D student, University of Nottingham)

classrooms were uncomfortably cold because of the downdraught of air from the chimneys; this was self-experienced by the author in one of the North West facing classrooms on the day of the visit on 14th March'2012. Hence on investigating the wind data of that day and inside and outside temperature, the following reasons were found behind the phenomenon:

- 1. The chimney vents are neither controlled by BMS nor manually and hence remain open throughout the year.
- 2. The dampers were malfunctioning.
- 3. The vents open in the direction of prevailing wind, which forces an air in-flow.
- 4. When the internal temperature is higher than the outside temperature it creates a negative pressure inside the classroom and hence the downdraught.

This raises a question whether the design efforts and cost involved in constructing these highly sophisticated air stacks or chimneys, in the Minster school, is justified or not. Another observation made from the design is that every classroom has same mode of ventilation, window design and size and chimney; irrespective of the direction they are oriented to. However the hypothesis is that every room will have different solar and wind exposure hence should have different ventilation strategies. Thus, to study the temperature difference between classrooms in opposite orientations, data loggers were left for a period of two weeks, one in a south east facing classroom (to be referred as Class 'A') and second in a north-west facing classroom (to be referred as Class 'B'). The data received is not conducive as the occupancy of both the classrooms was different and the under floor heating was on during this period, but nonetheless the temperature curves (Figure.5.) demonstrate two important points:

1. During day time, the temperature difference between the two classrooms is very small hence they are equally comfortable.

2. The temperature Class 'A' is lower than Class 'B'. This can be the result of wind flow which blew predominantly from South or East (Figure.6.) during that period and as per the wind data of Nottingham, the easterlies are colder than westerlies during March in this particular weather.

3.2. Onsite measurements and Simulation Results

3.2.1 Air flow assessment: In reference to the ventilation of the classrooms. onsite measurements were taken in order to record behavioral pattern of airflow in the classrooms and compare it to designer's intentions behind specific window design and provision of chimneys. The data was collected on 2^{nd} May'2012 when outside temperature was 23°C and wind direction was predominantly north or north east blowing at an average speed of 1.2m/s. The classroom 'A' was at 22.68°C and class 'B' at 18.5°C. To derive a meaningful result three conditions were chosen, first when the top pane of the external window is open, second when only bottom pane is open and third when both are open. However, in all the conditions chimney remain open vents as they are inoperable. A virtual sectional grid was made in Class 'A' well as 'B' between chimney opening and external window and then air velocity measurements were taken several number of times at ground 0.00m, desk 0.8m and 1.8m level till a pattern was found. The graphs (Fig. 7, 8 and 9) show that air distribution is best when the top and bottom both panes are open and also indicate that there is no stack effect in the classrooms. In North West facing classroom the air velocity near chimney vent was because of the push effect of the wind from West direction. This



Figure 5: Temperature of North West and South east class. Source: Yanti Chen (Ph.D student, University of Nottingham.)



Figure 6: Wind direction as recorded by EGNX, local weather station of Nottingham. Source: www.wunderground.com



Figure.7.Air Flow pattern in case of only bottom pane open. Source: Author



Figure.8. Air Flow pattern in case of only top pane open. Source: Author



Figure.9. Air Flow pattern when top and bottom both window panes are open. Source: Author

implies that the chimneys are redundant and may not be effective in profound wind velocities.

3.2.2 Thermal Performance: To assess the thermal performance of the classrooms 'A' and 'B', a computer model was done as per the present design assuming the worst case scenario when classrooms are used from 8:00a.m to 4:00p.m on every calendar day. The calendar was set to have winter days from 1st October to 2nd May and summer days from 3rd May to 30th September. The weather file chosen was of 2002 CIBSE design summer year Nottingham and the internal conditions were set assuming the building to be free running. The internal gains were taken considering the class to be fully occupied with 30 pupils and 1 teacher using a laptop and a projector. The infiltration was assumed to be at a



rate of 0.2 air changes per hour. As per the present condition, the chimney vents were taken to be open throughout the year but the external windows to be open only in summers during school hours. The graphs (Fig. 10 and 11) shows that in July (hottest month) the temperature curve of both the classrooms overlap each other and in



January (coldest month) they are parallel with a small difference of about 1°C, hence, this emphasizes that both the classrooms perform almost equally in winters as well as summers, hence the hypothesis is nullified and the designer is justified in providing same strategies in the two classrooms.

4. PROPOSAL FOR IMPROVEMENTS

As per the analysis done, it has been found that the classrooms are below the comfort criteria during most of the time in a year. Hence, several design modifications were investigated in order to increase the number of comfortable hours. Keeping the base case as present design, following alterations were tested for performance:

Case-1: If the classrooms had only external windows and the chimneys were closed. As per the standards for single sided ventilation, the depth of the room should not be more than 2.5 times the height of the room which is satisfied in the classroom design (height= 3.5m and depth =7m).

Case-2: If there was no top opening in the windows and only stack effect was a possible mode of ventilation.

Case-3: If the windows had solar shade with 50% shading proportion.

Case-4: If the windows were 3.5m wide instead of 4.5m.

Case-5: If the chimney vent was controlled by BMS such that in winters it remained closed but in summers it opened when the internal temperature exceeded 22°C.

Case-6: If the orientation of the classes was North-south instead of North West and South east.

Figure.12 illustrates that in a year, percentage of comfortable hours in class 'A' and 'B' can be increased from 5.62% and 5.27% to 13.73% and 11.58% respectively, by only providing BMS controlled chimney vents. Another solution may be to close the chimney vents and have single sided ventilation only.





5. CONCLUSIONS:

The design of Minster school comprehends environmental strategies for daylighting and

ventilation. The users were satisfied with the luminous environment of the classrooms, but complained about overheating and occasional downdraught from chimneys. Study demonstrated that the reason behind downdraught is that the chimney vents are inoperable and remains open throughout the year which may cause air infiltration in winters. The data recorded from site also shows that in summers, the stack ventilation through chimneys takes place only in case of high wind speed if the external window is open which unsuitable for working condition. In order to increase the no. of comfortable hours in a year from 5.62% to 13.73% and 5.27% to 11.58% in class A and B, respectively, it was found that the chimney vents should be controlled by BMS such that they remain closed in winters and conditionally open in summers. The graphs (Fig 13 and 14) show that this may also reduce heating demand from 27.12KW/sq.m to 3.7KW/sq.m and 26KW/sq.m to 1.8 KW/sq.m in class

The study manifests unsuccessful use of chimneys in the Minster school. Chimneys are sophisticated



¡Figure 13: Heating demand in present design. Source: Author



Figure 14: Heating demand in proposed design. Source: Author

building elements and a very effective mode of ventilation, but if not designed as per the climatic considerations, might have an adverse effect on the comfort of the users. This study will henceforth encourage the designer's to be discreet in judiciously using them.

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'A' and 'B' respectively.

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